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STRENGTH OF CONCRETE USING STONE DUST AND RECYCLED AGGREGATE AS PARTIAL REPLACEMENT OF NATURAL AGGREGATE

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Abstract

Concrete is prime construction material used in practice. No construction can be dreamed without use of concrete. The main constituents of concrete such as sand, stone and water are naturally available. These resources of natural aggregates (sand, stone) are limited and day by day the dependency on them must be minimized. The aim of this study was to investigate the possibility of using stone dust as partial replacement of fine aggregate and recycled aggregate as partial replacement of coarse aggregate. In the present study cubes and cylinders were cast to determine the compressive and split tensile strength of concrete made using stone dust and recycled aggregate as replacement of natural aggregate. Concrete of M25 grade was designed for a W/C ratio of 0.50 for the replacement of 20% coarse aggregate with recycled coarse aggregate and replacement of 30, 40, 50%, 60% and 70% of fine aggregate (sand) with stone dust. The test results indicate that stone dust can effectively been used as partial replacement of fine aggregate in concrete. It is found that the compressive and split tensile strengths of concrete increase on use of stone dust. It is observed that the compressive strength of concrete made using 20% recycled aggregate and 30% stone dust as replacement of coarse aggregate and fine aggregate respectively, is close proximity of referral concrete at 28 days.

Introduction

Concrete has been used as a major construction material ever since its inception. World over, last three to four decades have seen construction of numerous concrete structures with compressive strength of concrete in the range of 20-100 MPa. Indian construction industry also prefers use of concrete with compressive strength in the range of 20-85 MPa. The properties of concrete are influenced by the properties of the aggregate and water/cement ratio. Additives are those substances added to concrete that do not come under the binding agents and aggregates. The proper use of additives compromises certain beneficial effects to concrete, including improved quality, enhanced frost and sulphate resistance, control of strength development and improved workability. The possibility of using solid wastes in concrete has received increasing attention in recent years as a promising solution to the rising solid waste problem. There is a double environmental benefit by using industrial by-products. Prakash et al. (2007)

However, in recent years the wisdom of our continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection. In light of this, the availability of natural resources to future generations has also been realized. Given this background, the concept of sustainable development put forward almost a decade ago, at the 1992 Earth Summit in Rio de Janeiro, and it has now become a guiding principle for the construction industry worldwide. In fact many governments throughout the world have now introduced various measures aimed at reducing the use of primary aggregates and increasing reuse and recycling, where it is technically, economically, or environmentally acceptable. For example, the UK government has introduced a number of policies to encourage wider use of secondary and recycled coarse aggregate (RCA- defined as minimum of 95% crushed concrete) as an alternative to naturally occurring primary aggregates. These include landfill and future extraction taxes to improve economic viability, support to relevant research and development work Patil et al. (2013)

Dhir et al. (1999) reported that there is no decrease in strength for concrete containing up to 20% fine or 30% coarse recycled aggregates, but beyond these levels, there was a systematic decrease in strength as recycled aggregate content was increased. Patel and Pitroda (2013) reported the split tensile strength decreases when replacement of stone waste percentage increases when compare to traditional concrete. Nagbhusana et al. (2011) concluded that the compressive strength, split tensile strength and flexural strengths of concrete are not affected with the replacement of sand by CRP as fine aggregate up to 40%. Hence, CRP can be effectively used to replace natural sand, without reduction in the strength of concrete with CRP replacement level up to 40%.Kamala and Rao (2012) reported that the effectiveness of crushed ceramic waste as partial replacement of conventional coarse aggregate up to 40 percent, without affecting the design strength. Pofale and Quadri (2013) reported that the compressive strength of M25 concrete mix had increased by 22% with the use of crusher dust at 40% replacement of natural sand. Eren and Khaled Marar et al. (2007) reported that the optimum dust content is found to be 10% for compressive strength and split tensile strength. Increasing the dust content up to 30% improved compressive strength of concrete and minimum absorption obtained when dust content was 20%. Dust content higher than 30% decrease the compressive strength and dust content more than 20% increase the absorption of the concrete. Sahu et al. (2009) concluded that the utilization of crushed stone waste in concrete it was concluded that adding 40% sand may be replaced by stone waste in concrete without compromising quality of concrete.

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Materials and methods

Methodology: An experimental investigation was conducted to get the strength of specimens (cubes and cylinders) made with the use of stone dust and recycled aggregates as partial replacement of fine aggregates and coarse aggregates respectively. The strength of conventional concrete and other mixes were determined at the end of 7 and 28 days of moist curing. To study the effect of stone dust and recycled aggregates inclusion, cubes and cylinders of a design mix M25 grade concrete were cast. The 100 mm cubes were tested for compressive strength and the cylinder of size (75 mm × 150 mm) were tested for split tensile strength. The M25 mix proportion was (1:1.65:3) at w/c ratio of 0.50.

Cement

In the present study, Portland Pozzolana Cement (PPC) of a single batch was used throughout the investigation. The physical and chemical properties of PPC as determined are given in table 1. The cement satisfies the requirement of IS: 1489:1985. However, a more or less similar test result of cement was reported by Sandeep et al. (2014) and kujur et al. (2014).

Table 1. Properties of cement (Method of test refers to IS: 1489: 1985)

Properties	Experimental	Codal requirement [IS 1489 (Pt-1)-1985]
Normal consistency %	31.5%	
Initial setting time	165 min	(Not less than 30 min)
Final setting time	215 min	(Not more than 600 min)
Soundness of cement (Le chatelier expansion)	0.75 mm	(Not more than 10 mm)
Fineness of cement (% retained on 90 micron IS sieve)	3.77%	10%
Specific gravity of cement	2.67	3.15
Compressive strength		
7 days testing	33.0	22 N/mm^2(min)
28 days testing	43.2	33 N/mm^2(min)

Fine aggregate

The fine aggregate used was locally available river sand, which passed through 4.75 mm. Result of sieve analysis of fine aggregate is given in table 2. The specific gravity of fine aggregate is 2.43 and fineness modulus is 2.87.

Table 2. Sieve analysis for fine aggregate

S. NO.	Sieve Size	Weight Retained (g)	Cumulative Weight Retained	Cumulative % Weight Retained	Passing %	Standard % Weight Passing for Zone II
1	4.75mm	-	-	-	100	100
2	2.36 mm	50	50	5.0	95	75-100
3	1.18 mm	232	282	28.2	71.8	55-90
4	600µ	348	630	63.0	37	35-59
5	300 µ	296	926	92.6	7.4	8-30
6	150 µ	60	986	98.6	1.4	0-10
7	Pan	12	998	100	0	0
			Total = 287.4			

Fineness Modulus = 287.4/100= 2.87

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Coarse aggregate

Two aggregate sizes (20 and 10 mm) were used in this investigation. The specific gravity of coarse aggregate was 2.72 for both the fractions. Result of sieve analysis of 10 and 20 mm coarse aggregate are given in table 3 and 4 respectively. The 20 and 10 mm aggregate were mixed in the ratio of 60:40. However, more or less similar test results of aggregates were reported by Sandeep et al. (2014) and kujur et al. (2014).

Table 3. Sieve analysis for coarse aggregate of 10mm size

S. No.	Sieve Size	Weight Retained (g)	Cumulative Weight Retained	Cumulative % Weight Retained	Passing %
1	20 mm	-	-	-	100
2	10 mm	1680	1680	56	44
3	4.75mm	865	2545	84.83	15.17
4	2.36 mm	453	2998	100	-
5	1.18 mm	0	2998	100	-
6	600µ	0	2998	100	-
7	300 µ	0	2998	100	-
8	150 µ	0	2998	100	-
			Total = 640.83		

Fineness Modulus = 640.83/100=6.40

Table 4. Sieve analysis for coarse aggregate of 20mm size

S. No.	Sieve Size	Weight Retained (g)	Cumulative Weight Retained	Cumulative % Weight Retained	Passing %
1	40 mm	-	-	-	100
2	20 mm	290	290	9.66	90.34
3	10mm	2494	2784	92.8	7.2
4	4.75 mm	214	2998	100	-
5	1.18 mm	0	2998	100	-
6	600µ	0	2998	100	-
7	300 µ	0	2998	100	-
8	150 µ	0	2998	100	-
			Total = 602.46		

Fineness Modulus = 602.46/100=6.024

Stone dust

Stone dust was obtained from local stone crushing units of Bharatpur, Rewa Road, and Uttar Pradesh. It was initially dry in condition when collected, and was sieved before mixing in concrete. Result of sieve analysis of stone dust is given in table 5. Specific gravity of stone dust was 2.50 and Water absorption was 0.5%.

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Table 5. Sieve analysis of stone dust

S. No.	Sieve Size	Weight Retained (g)	Cumulative Weight Retained	Cumulative % Weight Retained	Passing %	Standard % Weight Passing for Zone II
1	4.75mm	4	4	0.4	99.6	100
2	2.36 mm	80	84	8.4	91.6	75-100
3	1.18 mm	336	420	42.0	58.0	55-90
4	600µ	510	930	93.0	7.0	35-59
5	300 µ	70	1000	100.0	0	8-30
6	150 µ	-	-	-	-	0-10
7	Pan	-	-	-	-	0
			Total Cumulative % Retained = 243.8			

Fineness Modulus = 243.8/100=2.44.

Water

Potable water was used for mixing and curing.

Mix Design

The mix design was carried out as per the recommendations laid down in IS-10262-2009.

The design mix proportion of 1:1.65:3 at W/C ratio of 0.50 were used for M25 grade of concrete and the cement content was 380 kg/m3, satisfying the requirements of minimum cement content (300 kg).

Results and discussion

Compressive strength

The result of compressive strength with replacement of stone dust for 7 and 28 d are presented in table 6 and its graphical representation is shown in fig.1.From the results, compressive strength of concrete with 30% replacement of stone dust and 20% replacement of recycled coarse aggregate is satisfactory to use.

Table 6. Compressive Strength of Different Mixes.

Sl. No.	Cube designation	%age replacement of stone dust	%age replacement of recycled aggregate	Average Compressive strength (N/mm^2)	
				7 days	28days
1	A1	0	0	25.9	33.1
2	A5	0	20	19.0	28.6
3	A6	30	20	21.5	32.9
4	A7	40	20	20.4	31.3
5	A8	50	20	19.9	29.8
6	A9	60	20	19.2	29.1
7	A10	70	20	20.3	30.8

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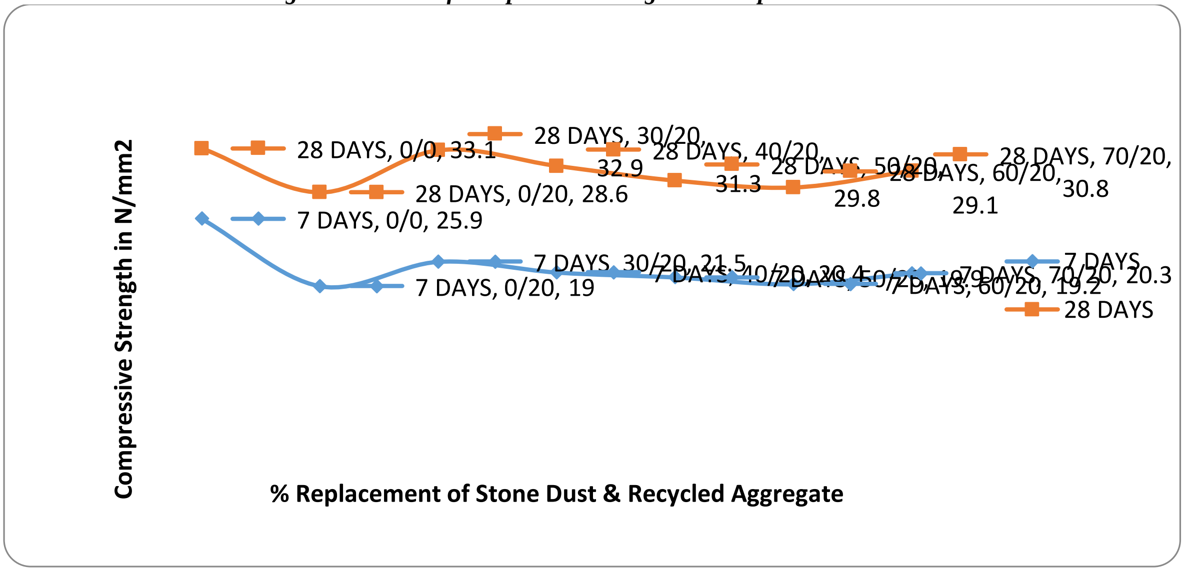
Results shows that 30% replacement of fine aggregate with stone dust and 20% replacement of coarse aggregate with recycled coarse aggregate, the compressive strength of concrete is marginally decreased at the age of 28 days compared to referral concrete.. It can be seen from table and figure that compressive strength is marginally decreased with addition of stone dust but only at 30% further addition of stone dust resulted in decrease of the strength that is similar to the finding of kujur et al. (2014) and reported similar trend and concluded that optimum replacement level is 40%.

Fig. 1. Variation of Compressive Strength with Replacement Level.



Split tensile strength

The split tensile strength of specimen were determined at 7 and 28 days and are given in table 7. The variation of split tensile strength with replacement level show in Fig 7. It is observed that the split tensile strength decreases marginally at 7 d with replacement level. However at 28 day, the split tensile strength decreases significantly with replacement level as compared to the referral concrete.

Table 7. Split Tensile Strength Of Different Mixes.

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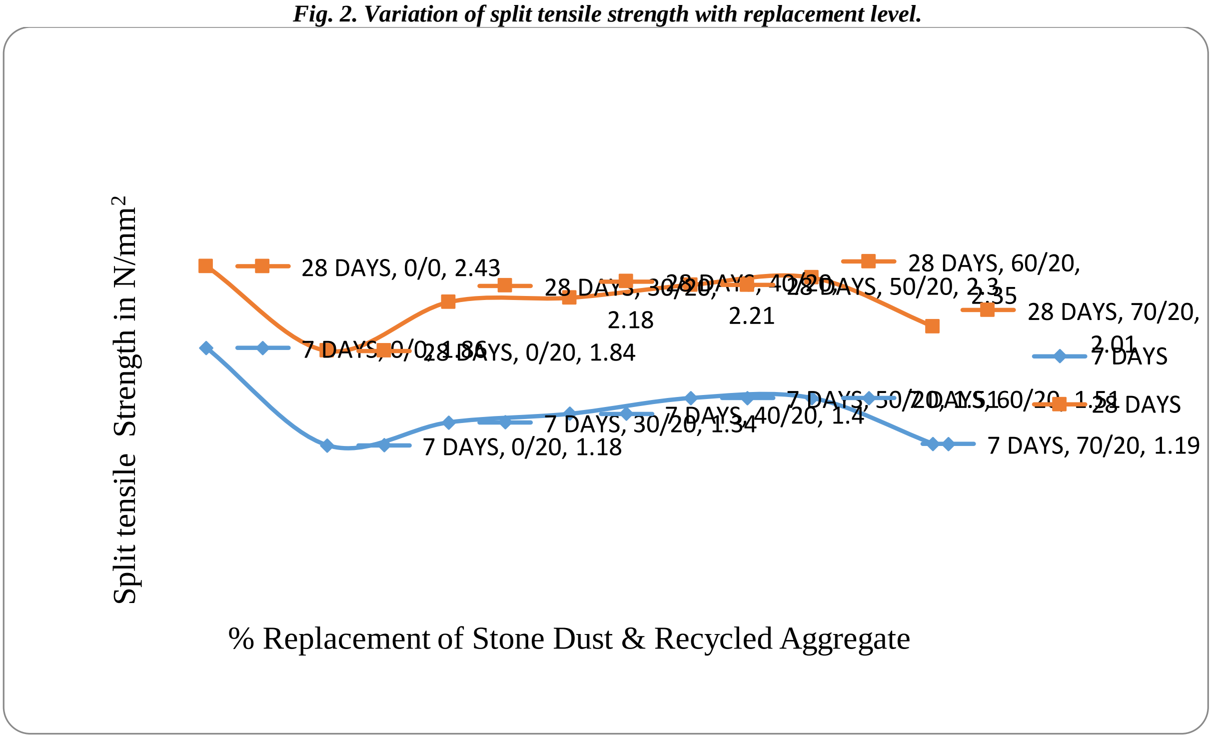
Sl. No.	CYLINDER designation	%age replacement of stone dust	%age replacement of recycled aggregate	Average Split tensile strength (N/mm^2)	
				7 days	28 days
1	B1	0	0	1.86	2.43
2	B2	0	20	1.18	1.84
3	B3	30	20	1.34	2.18
4	B4	40	20	1.40	2.21
5	B5	50	20	1.51	2.30
6	B6	60	20	1.51	2.35
7	B7	70	20	1.19	2.01

Results shows that with 20% replacement of recycled coarse aggregate; split tensile strength decreased by 23.95% at the age of 28 days compared to referral concrete whereas with 30%, 40%, 50%, 60% and 70% replacement of stone dust and 20% replacement of recycled coarse aggregate for each proportion there is reduction in split tensile strength by 10.12%, 8.97%, 5.51%, 3.42% and 17.28% respectively at the age of 28 days compared to referral concrete. As we increase the replacement factor of stone dust with same replacement factor of recycled coarse aggregate split tensile strength reduces because of low water absorption capacity of recycled aggregate.

Fig. 2. Variation of split tensile strength with replacement level.



Conclusion

From the above study, the following conclusions are obtained:

1. The compressive strength of 30% stone dust and 20% RCA sample is close proximity of the referral concrete. Thus it can be concluded that stone dust up to 30% with 20% recycled concrete aggregate is satisfactory to use.
2. Results shows that with partial replacement of stone dust with 50%, 60% and 70% and 10% recycled coarse aggregate, split tensile strength increased by 4.35%, 12% and 31.25% at the age of 28 days respectively as compared to referral

concrete whereas with 70% replacement of stone dust and 10% replacement of recycled coarse aggregate there is Increase in split tensile strength by 31.25% at the age of 28 days compared to referral concrete.

3. Split tensile strength of concrete with 30%, 40%, 50%, 60% and 70% replacement of stone dust and 20% replacement of recycled coarse aggregate for each proportion there is reduction in split tensile strength by 10.12%, 8.97%, 5.51%, 3.42% and 17.28% respectively at the age of 28 days compared to referral concrete. As we increase the replacement factor of stone dust with same replacement factor of recycled coarse aggregate split tensile strength reduces.

References

1. *Dhir, R.K., Limbachiya, M.C. and Leelawat, T. (1999) "Suitability of recycled concrete aggregate for use in BS 5328 designated mixes". Proc. of Civil Engg. Struct. Build.134 (August), pp.257-274.*
2. *Eren, Khaled and E.F.Irassar, S. V. Barai, (2007) Partial Replacement Using Crusher Stone Dust. IE (I) Journal-CV*
3. *IS 1489:1991 Portland-Pozzolana Cement - Specification - Part 1: Fly Ash Based, Bureau of Indian standard institution, New Delhi.*
4. *IS: 10262:1982 recommended guidelines for concrete mix design, Bureau of Indian standards, New Delhi.*
5. *IS: 2386-1963 Indian standards code of practice for methods of test for Aggregate for concrete, Bureau of Indian standard Institution, New Delhi.*
6. *IS: 383-1970 "Specification for Coarse and Fine Aggregates from natural sources for concrete" (Second revision).*
7. *IS: 456-2000 "Specifications for plain and reinforced concrete".*
8. *IS: 516-1959 "Method of test for strength of concrete Bureau of Indian standards". New Delhi, India.*
9. *Jain, M.E.M., Safiuddin, M. and Yusuf, K.M. (1999) "A study on the properties of freshly mixed high performance concrete". Cement Concr. Res. 29(9):1427-1432.*
10. *Kujur, F. E., Vikas, S, Anjelo, F. D., Ehsan, A., and Agarwal, V.C., (2104) "Stone Dust as Partial Replacement of Fine Aggregate in Concrete" Journal of Academia and Industrial Research (JAIR) Volume 3, Issue 5: 229-232.*
11. *Monish, M., Vikas, S., Agarwal, V.C., Rakesh, K., and Mehta, P.K. (2013) "Demolished waste as coarse aggregate in concrete" J. Acad. Indus. Res. 1(9): 540-542*
12. *Nagabhushana and Bai, H. S., (2011) "Use of crushed rock powder as replacement of fine aggregate in mortar and concrete". Indian Journal of Science and Technology, Volume 4, No. 8: 917-922.*
13. *Pofale, A.D. and Quadri, S.R. (2013) "Effective Utilization of Crusher dust in Concrete Using Portland Pozzolana Cement". International Journal of Scientific and Research Publications, Volume 3, Issue 8: 1-10.*
14. *Prakash, V.S., Krishnan, D. and Jeenu, G. (2007). Influence of fine stone dust on high strength concrete.32nd Conf. on our world in concrete and structures, 28-29 August 2007, Singapore Article Online Id: 100032054, 2007.*
15. *A. K. Sahu, Sunil Kumar, A. K. Sachan (2009) Utilization of Crushed Stone Waste in Concrete. NCACM. Methodologies and Management (AC3M-09) 21-22 January, 2009 Hyderabad, India.*